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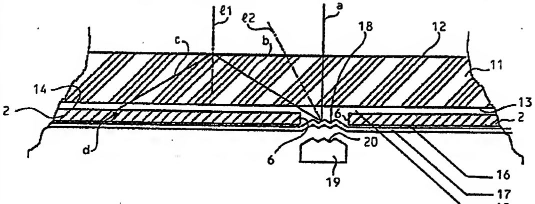

(57) Abstract

A photovoltaic solar panel comprising a transparent bearing plate having a first surface for receiving sunlight and a second surface which is provided with one or more solar cells so as to form a panel surface comprising active and inactive regions, as well as directing means being related as regards position to inactive regions of the panel surface, in order to direct at least part of the sunlight that would otherwise be incident on said inactive regions at active regions of the panel surface. A method for manufacturing such a photovoltaic solar panel by providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly with the interposition of a second intermediate layer, laminating said assembly by using heat and pressure, and treating, processing or forming the bearing plate, the coating or the metal strips provided on the metal strips, at positions related to inactive regions of the panel surface, or adding optical directing means to the assembly prior to laminating.

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A photovoltaic solar panel and a method for producing same.

The invention relates to a photovoltaic solar panel comprising a transparent bearing plate having a first surface for receiving sunlight and a second surface which is provided with one or more solar cells so as to form a panel surface comprising active and inactive regions, and to a method for producing same, said method comprising the steps of providing said one or more solar cells on the bearing plate with the interposition of a first intermediate layer, applying a reflective coating to said subassembly with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure.

A photovoltaic solar panel is used for generating electricity from sunlight, by means of (generally) a plurality of solar cells, which are electrically connected in series and which are placed in a matrix of for example 4 x 9 solar cells of 10 cm by 10 cm. The solar cells are thereby spaced a few millimetres apart, which leads to a loss of sunlight between and around the solar cells, just like the metal strips on the sunlight-receiving surface of the solar cells, which are used for the series connection.

The two main specifications of a photovoltaic solar panel are the peak power output with a predetermined solar radiation and the cost price in guilders per peak power unit. When trying to improve photovoltaic solar panels it is therefore attempted to increase the peak power to be output per solar cell surface and to reduce the cost price, with the restriction of a predetermined minimum power density per unit area.

Solar cells are expensive, typically costing Dfl 800.- per m² at the moment. The other surface-related materials of the photovoltaic solar panel are comparatively inexpensive, typically Dfl 200.- per m² at the moment. Consequently photovoltaic solar panels may be improved by enhancing the efficiency of the solar cells, making the solar cells cheaper, finding cheaper materials for the manufacture of the photovoltaic solar panels and making a more efficient use of the solar cell surface area in relation to the other panel surface area.

The latter possibility is used with so-called concentrator solar cells, whereby a system of lenses projects sunlight concentrated 10 - 100 times onto the solar cell surface. A drawback is thereby the fact that the solar panel must constantly be directed at the

sun at right angles, in order to ensure a satisfactory operation, which renders this solution costly after all.

The panel surface of a photovoltaic solar panel comprises active regions, in which incident sunlight results in current produced by the solar panel, and inactive regions, in which no current or hardly any current is generated. Sunlight incident on inactive regions of the solar panel is not absorbed by the semiconductor material of the solar cells, but by other materials, or reflected from the solar panel again. Examples of inactive regions are the spaces between and around the solar cells and the two metal strips at the front side of the solar cells of the photovoltaic solar panel referred to by way of example, which are used for the series connection of the solar cells.

The object of the invention is to improve the above-described photovoltaic solar panel in such a manner, that sunlight incident on inactive regions of the panel surface of the known solar panel, which is at least for the greater part lost, that is, which is not used to generate electricity, is intercepted and rendered suitable for the generation of electricity as yet, as a result of which the peak power to be output can be increased (for example by more than 5 W), and in order to accomplish that objective the invention provides a photovoltaic solar panel of the kind referred to in the introduction, which is characterized in that said photovoltaic solar panel comprises directing means being related as regards their position to inactive regions of the panel surface, in order to direct at least part of the sunlight that would otherwise be incident on said inactive regions at active regions of the panel surface.

These directing means may be realized in a highly cost-efficient manner.

The directing means may comprise reflection means, diffraction means, diffusion means or a combination thereof. The reflection means and/or diffusion means may be provided on the second surface of the bearing plate and/or on the surface of said one or more solar cells forming part of the panel surface, whereby said reflection means and/or diffusion means are arranged to reflect or diffuse incident sunlight thereon against the first surface of the bearing plate in such a manner that said incident sunlight is directed at active regions of the panel surface as a result of internal reflection within the bearing plate. The diffraction means may be provided on the first surface of the bearing plate instead of or in combination with the reflection means and/or diffusion means set up

in the manner discussed above, and be arranged in such a manner that incident sunlight thereon is deflected at active regions of the panel surface.

More in particular, when said one or more solar cells on the panel surface are provided with one or more metal strips for the collection of current and, in some cases, mutual series connection, said metal strips may be formed with longitudinal V-shaped grooves and thus form part of said reflection means.

Furthermore the reflection means may comprise reflective strips formed with longitudinal V-shaped grooves, which are provided along one or more sides of said one or more solar cells on the second surface of the bearing plate.

When the photovoltaic solar panel is provided with a reflective coating at the surface opposite the panel surface, this coating may furthermore comprise longitudinal V-shaped grooves along one or more sides of said one or more solar cells, which thus form part of the reflection means. More specifically, the reflective coating may be provided in longitudinal V-shaped grooves formed at corresponding places in the second surface of the bearing plate.

The diffusion means may comprise a substance or micro-roughness having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate, which is applied to the second surface of the bearing plate, in places which correspond with inactive regions of the panel surface. When the bearing plate is made of glass having an index of refraction of about 1.5, and the solar panel is used in air, said critical angle is about 42 degrees.

Finally the bearing plate of the proposed photovoltaic solar panel may comprise longitudinal V-shaped grooves formed in the first surface of the bearing plate, in places which correspond with inactive regions of the panel surface, said V-shaped grooves thus forming part of the diffraction means.

It is not necessary to use a plurality of solar cells in the proposed photovoltaic solar panel. According to the present invention it is possible to use a single, more in particular a high-quality and therefore costly solar cell, which is surrounded by a relatively large area of reflective strips or reflector plates provided with longitudinal V-shaped grooves, which are mitre-formed in case of a rectangular solar

cell. In this manner an inexpensive concentrator solar cell is formed, in contrast to the expensive solar cell comprising the system of lenses, which by itself might also be used in greater numbers in photovoltaic solar panels again. Furthermore it will be apparent that the solar cells do not have to be rectangular, they may also be circular or rounded.

The invention may also be used with all types of flat plate panels with for example solar cells of semicrystalline silicon, amorphous silicon and other semiconductors, as well as with circular and rounded monocrystalline solar cells, whereby the problem of the limited packaging density can be solved in accordance with the present invention.

With the same object in mind the invention also provides methods for manufacturing the proposed photovoltaic solar panel, whereby other methods are conceivable, however, which also applies to the concrete embodiments of the proposed photovoltaic solar panel, of course, the only essential aspect being that the photovoltaic solar panel is provided with means for directing light which would otherwise be incident on inactive regions of the panel surface and could not be used for generating electricity at active regions of the panel surface, as a result of which it becomes possible to used said sunlight for generating electricity after all, whereby said directing means are related as regards their position to the aforesaid inactive regions.

In order to accomplish that objective the proposed methods of the kind referred to in the introduction are different from the prior art in that they comprise any one of the following measures or a suitable combination thereof.

Prior to providing the second intermediate layer reflective strips formed with longitudinal V-shaped grooves may be provided along one or more sides of said one or more solar cells on the first intermediate layer. The term "along one or more sides of said one or more solar cells" is thereby understood to mean around a solar cell, and between and around a plurality of solar cells. Furthermore the term "strips" is also understood to mean plates, whilst the term "along" is understood to mean directly along or at a higher or lower position along said sides.

When said one or more solar cells are fitted with one or more metal strips for the collection of current, and in some cases, mutual series connection, prior to being provided, metal strips formed with longitudinal V-shaped grooves may be used or a substance or micro-roughness having a large diffuse reflection over an angle greater than

the critical angle for total reflection at the first surface of the bearing plate may be applied to a surface of the metal strips which will at a later stage form part of the panel surface, prior to said one or more solar cells being provided.

The metal strips for the collection of current may be wider than has been usual so far, as incident light on said strips is still effectively deflected at the active region. As a result of this measure the ohmic losses in the series connection are reduced without less current being produced by the solar panel.

Finally the strips between which lie two cells and which are provided with a diffuse reflector or V-shaped grooves, may be used as a series connection between two adjacent solar cells if they have been made conductive by a metallic reflector, for example, as a result of which the ohmic resistance from cell to cell is reduced.

Prior to providing said one or more solar cells a substance or micro-roughness having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate may be applied to the second surface of the bearing plate, along one or more sides of said one or more solar cells, in places which correspond with one or more strip-shaped regions.

Furthermore an assembly, a sort of grid, of reflective strips may be placed directly between and around the cells, so that only one operation is necessary.

For the laminating process a mould may be used, which is formed in such a manner that longitudinal V-shaped grooves are formed in the whole of intermediate layers and coating along one or more sides of said one or more solar cells, in places which correspond with one or more strip-shaped regions.

A bearing plate may be used, which is formed with longitudinal V-shaped grooves along one or more sides of said one or more solar cells on the second surface, in places which correspond with one or more strip-shaped regions, into which grooves the coating is pressed during laminating.

Said V-shaped grooves preferably have walls which are inclined in such a manner that the angle which the normal on said walls includes with the normal on the bearing plate is selected such that this results in a maximum angular independence, being about 30 degrees in case

of a bearing plate of glass having an index of refraction of about 1.5 in air.

Finally a bearing plate may be used, which is formed with longitudinal V-shaped grooves along one or more sides of said one or more solar cells on the first surface, in places which correspond with one or more strip-shaped regions.

When circular or rounded solar cells are used the strips will naturally be shaped accordingly, that is, arched portions will be cut out of said strips.

The invention will be described in more detail hereafter by way of example, in a non-limitative sense, with particular reference to possible embodiments illustrated in the drawing, in which:

Figure 1 is a general plan view of a photovoltaic solar panel as proposed and according to the prior art;

Figure 2 is a larger-scale detail view of a small part of the photovoltaic solar panel of Figure 1;

Figure 3 is a further detail view of the detail view of Figure 2, being modified in accordance with the present invention;

Figure 4 is a view corresponding with Figure 3, in this case in sectional view, however;

Figures 5 - 7 are views corresponding with Figure 4, showing other embodiments of the proposed photovoltaic solar panel, however; and

Figures 8 and 9 show a concentrator solar cell in accordance with the present invention, in plan view and in sectional view respectively.

Figure 1 shows a photovoltaic solar panel at 1, whilst numerals 2 and 3 indicate solar cells and current-carrying metal strips respectively, numeral 4 finally indicating an interconnection of respectively two metal strips 3 of two neighbouring (final) solar cells 2 and the series connection therebetween as a part of the series connection of all solar cells, which is furthermore realized on the rear side (not shown) of the solar panel 1 opposite the illustrated front side of the solar panel. By itself this is conventional, as is the illustrated arrangement in a matrix of the solar cells 2, which typically have a thickness of for example 250 μm. (Amorphous silicon solar cells typically have a thickness of about 1 μm).

Inactive regions are formed in the solar panel of Figure 1, by a panel surface portion not covered by solar cells 2 and by a surface portion of the solar cells 2 which is not covered by metal strips 3, and also the series connection 4. Active regions are formed by surface portions of the solar cells 2 not covered by metal strips 3.

This conventional solar panel 1 can be changed into a solar panel according to the present invention merely by modifying the "free" surface of the metal strips 3, by forming the metal strips 3 with longitudinal V-shaped grooves or applying a micro-roughness or substance having a large diffuse reflection over an angle exceeding a predetermined magnitude on said grooves, whereby the former measure may be taken before placing the metal strips 3 on the solar cells 2, and whereby the latter measure may take place prior to or after placing the metal strips on the solar cells 2. Essential is thereby only the fact that the metal strips 3 are suitably made to reflect sunlight or to diffuse sunlight.

Figure 2 shows parts of two neighbouring solar cells 2 in more detail, whilst also parallel current collecting conductors 5 are shown, with which respective metal strips 3 are connected in such manner as to cross them perpendicularly, and which, strictly speaking, are also inactive regions, but which may form part of the proposed directing means by forming them in the shape of an inverted V, for example. Reference numerals 6 indicate sides of respective solar cells 2.

The detail shown in Figure 2 may be that of a proposed solar panel, when one of the above measures with regard to the metal strips 3 has been taken.

Figure 3 is a further detail, within a circle indicated at 100, of a part of Figure 2 enclosed by the circle indicated at 10, in this case modified in accordance with the invention by incorporating a reflective strip 7 having longitudinal V-shaped grooves 8 along a side 6 of a solar cell 2. Put differently, the strip 7 is incorporated between sides 6 of two neighbouring solar cells 2. The strip may for example be made of a metal or of a metallized plastic material. For the rest the same reference numerals are used as in Figure 2.

Figure 4 is a sectional view of Figure 3. In Figure 4 a transparent bearing plate, typically of glass, is indicated at 11, reference numerals 15 and 16 indicate a first and a second intermediate layer respectively, typically of a plastic foil, typically EVA for example, whilst reference numeral 17 indicates a reflective coating,

typically a metal-containing layer of plastic material, typically TEDLAR/aluminium/TEDLAR. The bearing plate 11 comprises a first surface 12 for receiving sunlight, and a second surface 13, which is provided with a plurality of solar cells 2 so as to form a panel surface 14 comprising active and inactive regions.

Also referring to Figure 1, the metal strips 3 substantially extend in one direction in that case, the "longitudinal direction" of the solar panel 1. Series connection of the solar cells 2 means that metal strips 3 of the front surface of a certain solar cell 2 extend in the direction of the rear surface of an adjacent solar cell 2, which implies that said series connection crosses the direction extending perpendicularly to said one direction, the "transverse direction", of the panel 1. This has hardly any consequences for reflective strips 7 extending in the longitudinal direction of the panel 1, therefore, but it does have consequences for reflective strips 7 provided crosswise between solar cells 2, which strips are connected in series by means of metal strips 3. This has to be taken into account, therefore. Several solutions are possible, a few of which will be discussed hereafter.

The reflective strips 7 may be left out in places where metal strips 3 are present. This implies that the reflective strips 7 are provided in smaller pieces, and that no pieces of reflective strips 7 are provided in places where metal strips 3 are present.

The reflective strips 7 may be provided with recesses, in such a manner that the metal strips 3 can be freely interconnected.

The reflective strips 7 may be flexible, possibly only during their manufacture, so that they can be provided behind or in front of the metal strips 3.

It is emphasized that the measures indicated above cannot only be used with regard to metal strips 3 forming part of the series connection, which extend from the front side to the rear side of the panel 1, but also with regard to crossing reflective strips 7.

The principle of the invention is indicated by the light beams a, b, c and d. An incident light beam a on the first surface 12 of the bearing plate 11, at right angles in this case, is propagated to a wall of groove 8 without being deflected, whereupon it is reflected, at an angle with the normal on said wall which is equal to the angle of incidence with respect to said normal, to the first surface 12 of the bearing plate 11, where it is reflected, as a result of total internal

reflection, whereby the angle of incidence is equal to the angle of emergence with respect to the first surface 12 of the bearing plate 11, to one of the solar cells 2 and absorbed therein, as shown by the light beams b, c and d respectively. Light beam a thus contributes, in the form of light beam b, to conversion into current to be collected along the metal strip 3 of Figure 2, said conversion taking place in the active region of solar cell 2.

More generally, the proposed photovoltaic solar panel 1 comprises directing means (for example the reflective strips 7 formed with longitudinal V-shaped grooves 8 in the aforesaid strip-shaped space or the aforesaid paint on the metal strips 3), which are related as regards their position to inactive regions (for example the strip-shaped region between sides 6 of solar cells 2 in Figure 2, and metal strips 3, if the aforesaid measures with regard to said metal strips have not been used), in order to direct at least part of sunlight that would otherwise be incident on said inactive regions at active regions of the panel surface 14, and thus of the solar cells 2.

The directing means may therefore comprise reflection means, such as the reflective strip 7 formed with longitudinal V-shaped grooves 8, diffusion means, such as a (metallic) paint, or diffraction means yet to be described with reference to Figure 7.

As already explained before, said reflection means (7, 8) and/or diffusion means (the aforesaid paint) may thereby be applied to the second surface 13 (with the interposition of a first intermediate layer 15 in the illustrated case) of the bearing plate 11 and/or the surface of the solar cells 2 forming part of a panel surface 14, whereby said reflection means (7, 8) and/or diffusion means (the aforesaid paint) are arranged so as to reflect or diffuse, as the case may be, incident sunlight (a) thereon to the first surface 12 of the bearing plate 11, in such a manner that said incident sunlight is directed at active regions of the panel surface 14, and thus of the solar cells 2, as a result of internal reflection (b, c) in the bearing plate 11.

As will be discussed with reference to Figure 7, the diffraction means may be provided at, that is on top of or inside, the first surface 12 of the bearing plate 11, and be arranged in such a manner that incident sunlight thereon is deflected to active regions of a panel surface 14.

In Figure 5 the reflective coating 17 comprises longitudinal V-shaped grooves along one side 6 of a solar cell 2, or more precisely in that case, between two sides 6 of two neighbouring solar cells 2, which grooves are formed during laminating by using a mould 19 (shown in Figure 5) comprising grooves 24 that correspond with the grooves 18, which mould is shaped in such a manner that longitudinal V-shaped grooves are formed in the whole of intermediate layers 15 and 16 and coating 17, but in particular in the reflective layer 17, along one or more sides 6 of one or more solar cells 2, in places which correspond with one or more strip-shaped regions.

The embodiment of Figure 4 may be formed by providing reflective strips 7 formed with longitudinal V-shaped grooves 8 on the first intermediate layer 15 along one or more sides 6 of said one or more solar cells 2, prior to providing the second intermediate layer 16. The strips may be made of a metal or of a metallized plastic material.

One embodiment according to Figures 2 and 4 may be formed by providing a metallic paint having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate along one or more sides 6 of said one or more solar cells 2, in places which correspond with one or more strip-shaped regions, prior to placing said one or more solar cells 2 on the second surface 13 of the bearing plate 11. According to an advantageous alternative the directing means, the paint in this case, may be provided after the solar cells 2 have been placed, whereby the solar cells 2 may serve as a mask for applying said directing means.

Figure 6 shows a variant of Figure 5. In Figure 6 the reflective coating 17 is provided in longitudinal V-shaped grooves 21 formed in corresponding places in the second surface 13 of the bearing plate 12, as a result of which complementary grooves 18 are formed in the reflective coating 17.

It is furthermore noted that like numerals indicate like parts in the various Figures.

The method associated with Figure 6 is such that a bearing plate 11 is used, which is formed with longitudinal V-shaped grooves 21 along one or more sides 6 of said one or more solar cells 2 on the second surface 13, in places which correspond with one or more strip-shaped regions, into which said coating 17 is pressed during laminating.

Not shown in the drawing, but for example referring to Figure 5, the proposed diffusion means may comprise a metallic paint having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface 12 of the bearing plate 11, in places which correspond with inactive regions of the panel surface 14. As already said before, this critical angle is 42 degrees when the bearing plate 11 is made of glass having an index of refraction of about 1.5, and the solar panel is used in air. The proposed method associated therewith comprises the application of the said metallic paint along one or more sides 6 of said one or more solar cells, in places which correspond with one or more strip-shaped regions, prior to providing said one or more solar cells 2 on the second surface 13 of the bearing plate 11. According to a sub-alternative with regard to the metal strips 3, the said metallic paint may be applied to a surface of the metal strips 3 at a later stage forming part of the panel surface 14 prior to providing said one or more solar cells.

In Figure 7 the bearing plate 11 comprises longitudinal V-shaped grooves 22 provided in the first surface 12 of the bearing plate 11, in places which correspond with inactive regions of the panel surface 14, said grooves deflecting incident light beams a into light beams e, which are absorbed in the solar cells 2 as light beams d.

A method for manufacturing a photovoltaic solar panel 1 in accordance with the embodiment shown in Figure 7 thus uses a bearing plate 11, which is provided with longitudinal V-shaped grooves 22 along one or more sides 6 of said one or more solar cells 2 on the first surface 12, in places which correspond with one or more strip-shaped regions.

Still referring to Figure 7, it is again noted that a diffraction structure 22 on top of the bearing plate 11 is also possible. This is achieved by translating the V-shaped grooves of Figure 7 in upward direction, as it were.

The concentrator cell 30 in Figures 8 and 9 comprises a high-quality and by itself relatively costly solar cell 2, which again comprises current collecting conductors 5 and in this case a single metal strip 3. Also in this case metal strips 7 comprising longitudinal V-shaped grooves 8 are used, as in the embodiment of Figures 3 and 4, which are relatively wide in this case, however, and which are provided on all sides 6 of the solar cell 2, and which are for that purpose mitre-formed at the ends at 71. One or more concentrator solar cells 30 may be incorporated

in a photovoltaic solar panel 1. Furthermore the operational principle is the same as that of the above-described embodiments, so that it will not be discussed in more detail here. The fact is, however, that because the surface area of the directing means is much larger in this case than the surface area of the solar cell, a considerable part of the internally reflected sunlight does not land directly onto the solar cell surface, but onto the surface of the directing means again, after which said sunlight is directed at the solar cell surface as yet, as a result of repeated reflection. It is furthermore noted that also with the solar cells 2 discussed before the directing means may and preferably will be provided on all sides 6, of course.

Now the principles of the invention will be discussed in more detail with reference to Figure 5, in which the normal on the first surface 12 of the bearing plate 11 is indicated at $\ell 1$, and the normal on one of the slopes of the grooves 18 in the coating 17 at $\ell 2$.

Important parameters for the effect of the invention are the coefficient of transmission, the thickness of the bearing plate 11 and the smoothness of the first surface 12 of the bearing plate 11, which is typically made of glass having a thickness of 3 mm, the angle of reflection α and the reflectivity of the reflection means, whereby the angle of reflection α is formed by the normals $\ell 1$ and $\ell 2$, the spacing A between (the sides 6 of) two neighbouring solar cells 2, the texture of the active region of the solar cells 2, the angle of incidence $\theta 1$ of sunlight and the angle $\theta 2$ at which the sunlight is incident on the first surface 12 of the bearing plate 11, both with regard to the normal $\ell 1$.

The required minimum angle at which the sunlight reflected by the reflection means (18) or diffusion means is to reach the second surface 13 of the bearing plate again is about 42 degrees with respect to the normal $\ell 1$. This is the critical angle for total reflection at a glass-air interface, whereby the index of refraction of the glass is about 1.5. When another material is used for the bearing plate 11 and/or when an environment other than air is used, said critical angle will have a different magnitude. In the case of a glass/air interface the critical angle is reached when the angle of reflection α is more than about 21 degrees with respect to the normal $\ell 1$.

The maximum angle allowed for the inclination of the grooves (18 in Figure 5) between two solar cells 2 is 30 degrees, since there will otherwise be shadows caused by the summits of the grooves.

The maximum spacing Amax between two solar cells, with an angle of incidence of light of 0 degrees, is obtained by:

$$Amax = 2 \cdot D \cdot \tan 2\alpha,$$

where D is the thickness of the bearing plate 11 (plus the thickness of the first intermediate layer 15).

For D = 3 mm and α = 30 degrees this formula gives Amax = 1.04 cm, and for α = 22 degrees this gives Amax = 0.58 cm. The table 1 below illustrates the relation between the angle of reflection α, the angle of incidence $\theta 1$ of sunlight, the maximum spacing Amax that can be bridged and the effectiveness of the reflection means, whilst the next table 2 illustrates the relation between angle of reflection α, the spacing between neighbouring solar cells and surface gain with an angle of incidence $\theta 1$ of sunlight of 0 degrees on the one hand and an angle of incidence $\theta 1$ of 20 degrees on the other hand.

TABLE 1

ANGLE OF REFLECTION α (DEGREES)	ANGLE OF INCIDENCE $\theta 1$ OF SUNLIGHT	MAXIMUM SPACING TO BE BRIDGED Amax (mm)	PERCENTAGE OF SUNLIGHT RECEIVED BY REFLECTION MEANS AND REFLECTED TO ACTIVE REGIONS (%)
20	0	5.0	23
20	-20	8.6	89
20	+20	2.3	4
25	0	7.2	90
25	-20	12.4	85
25	+20	3.8	10
30	0	10.4	87
30	-20	20.3	52
30	+20	5.7	91
35	0	16.5	54
35	-20	49.3	14
35	+20	8.4	86

TABLE 2

ANGLE OF REFLECTION α (DEGREES)	SURFACE GAIN WITH ANGLE OF INCIDENCE θ1 OF SUNLIGHT OF 0 DEGREES (cm^2)	SURFACE GAIN WITH ANGLE OF INCIDENCE θ1 OF SUNLIGHT OF 20 DEGREES (cm^2)	SPACING BETWEEN NEIGHBOURING SOLAR CELLS (mm)
20	50	75	3
25	196	148	3
30	188	171	3
35	116	112	3
20	83	107	5
25	326	246	5
30	313	285	5
35	193	186	5
20	83		Amax = 5.0
25	469		Amax = 7.2
30	651		Amax = 10.4
35	637		Amax = 16.5

From tables 1 and 2 it appears, among other things, that an angle of reflection α of 30 degrees provides the greatest angular insensitiveness.

For the diffraction means (22) in Figure 7 it applies that the angle α, at which the deflected light beam c, e just fails to reach the other side of the V-shaped groove 22, is 60 degrees, starting from an index of refraction of the bearing plate 11 of n - 1.5 and θ1 = 0 degrees. More generally it applies for this critical angle that it is equal to the angle where $90-2\cdot\alpha-\theta1 = 0$ with $\sin(\alpha+\theta1)/\sin(\theta2) = n$, where θ2 is the angle of the coupled-in light beam with the normal ℓ1 on the first surface 12. Here the optimal angle of 30 degrees does not apply, therefore. For the maximum spacing Amax it applies in this case: $Amax = D\cdot\tan(\alpha-\theta2)$. With α = 60 degrees, it applies that Amax = 1.5.

In a photovoltaic solar panel according to the present invention an effective surface gain of nearly 200 cm^2 is possible when the spacing between the solar cells is 3 mm, and a gain of more than 300 cm^2 is possible with a spacing of 5 mm.

When the gain obtained with metal strips according to the invention, with a spacing to be bridged of 2 mm, is taken into account, this results in an additional effective surface area of 125 cm^2. This provides a total additional surface area of more than 400 cm^2, which may virtually be activated on a total cell area in the panel of 3,600 cm^2, which means that the capacity of the solar panel is increased by more than 11%.

There is an annual variation in the position of the sun relative to the earth. In summer there is more sunlight than in winter. By suitably selecting the angle of the V-groove the present invention may also be used to reduce the difference between winter and summer in generating energy. Asymmetric V-grooves will have to be used for that purpose, the apex still being 120 degrees. In that case the reflective strips comprising V-shaped grooves will have to be oriented east-west, however.

As has just been described, the present invention may be used to increase the capacity of the panel. Furthermore the present invention makes it possible to space the solar cells further apart, without decreasing the power density thereby. Furthermore it would be possible to use fewer solar cells per photovoltaic solar panel, without the total capacity of the solar panel being reduced.

When laminating the solar panels 1 the pressure is generally applied by vacuum suction of the stack consisting of bearing plate 11, solar cells 2, first and second intermediate layers 15 and 16 and reflective coating 17. The following alternative methods for manufacturing solar panels may be mentioned.

Bonding the solar cells 2 directly to the bearing plate 2. Although additional pressure may be used here, an extra temperature increase in not necessary. The intermediate layers 15, 16 may consist of a transparent adhesive in that case.

In case plastic bearing plates 11 are used the solar cells 2 may be fused with the bearing plate 11.

In the case of amorphous silicon solar cells 2 and other solar cells 2, which need the bearing plate for their strength, the semiconductor material of the solar cell 2 may be applied to the bearing plate 11 directly, for example by means of a deposition or growth process. In this case the metal strips 3 are provided in a different, suitable manner.

Furthermore it is noted that the intermediate layers 15, 16, that is the binding agent between the solar cells 2 and the bearing plate 11 of for example glass, may have a slightly different index of refraction than the glass itself. In that case also a change of reflection and a change of angle take place at the boundary surface between bearing plate 11 and intermediate layer 15, for example. The change of reflection and the change of angle will be small, however, because of the small differences between the two respective indices of refraction.

Finally it is noted that hereinabove V-shaped grooves have been mentioned. The invention is not limited to said grooves, however, alternative examples being asymmetric V-shaped grooves for those places, for example along the edge of a panel, where the reflection is to be deflected in particular in one direction and not in two directions, and pyramidal reflection structures, where incident sunlight is not led perpendicularly to the cell edge, but at an angle to the cell.

CLAIMS

1. A photovoltaic solar panel comprising a transparent bearing plate having a first surface for receiving sunlight and a second surface which is provided with one or more solar cells so as to form a panel surface comprising active and inactive regions, characterized in that said photovoltaic solar panel comprises directing means being related as regards their position to inactive regions of the panel surface, in order to direct at least part of the sunlight that would otherwise be incident on said inactive regions at active regions of the panel surface.

2. A photovoltaic solar panel, characterized in that said directing means comprise reflection means, diffraction means, diffusion means or a combination thereof.

3. A photovoltaic solar panel according to claim 2, characterized in that said reflection means and/or diffusion means are provided on the second surface of the bearing plate and/or on the surface of said one or more solar cells forming part of the panel surface, whereby said reflection means and/or diffusion means are arranged to reflect or diffuse incident sunlight thereon against the first surface of the bearing plate in such a manner that said incident sunlight is directed at active regions of the panel surface as a result of internal reflection within the bearing plate.

4. A photovoltaic solar panel according to claim 2 or 3, characterized in that said diffraction means are provided on the first surface of the bearing plate, and are arranged in such a manner that incident sunlight thereon is deflected to active regions of a panel surface.

5. A photovoltaic solar panel according to any one of the claim 2 - 4, wherein said one or more solar cells on the panel surface are provided with one or more metal strips for the collection of current and, in some cases, mutual series connection, characterized in that said metal strips are formed with longitudinal V-shaped grooves and thus form part of said reflection means.

6. A photovoltaic solar panel according to any one of the claim 2 - 5, characterized in that said reflection means comprise reflective strips formed with longitudinal V-shaped grooves, which are provided along one or more sides of said one or more solar cells on the second surface of the bearing plate.

7. A photovoltaic solar panel according to any one of the claim 2 - 5, characterized in that said photovoltaic solar panel is provided with a reflective coating at the surface opposite the panel surface, characterized in that said reflective layer comprises longitudinal V-shaped grooves along one or more sides of said one or more solar cells, which thus form part of said reflection means.

8. A photovoltaic solar panel according to claim 7, characterized in that said reflective coating is provided in longitudinal V-shaped grooves formed in corresponding places in the second surface of the bearing plate.

9. A photovoltaic solar panel according to any one of the claim 2 - 8, characterized in that said diffusion means comprise a substance or micro-roughness having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate, which is applied to the second surface of the bearing plate, in places which correspond with inactive regions of the panel surface.

10. A photovoltaic solar panel according to any one of the claim 2 - 9, characterized in that said bearing plate comprises longitudinal V-shaped grooves formed in the first surface of the bearing plate, in places which correspond with inactive regions of the panel surface, said V-shaped grooves thus forming part of said diffraction means.

11. A photovoltaic solar panel according to claims 5, 6, 7, 8 or 10, characterized in that the angle which the normal on the walls of said V-shaped grooves includes with the normal on the bearing plate is selected such that this results in a maximum angular independence, being about 30 degrees in case of a bearing plate of glass having an index of refraction of about 1.5 in air.

12. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, characterized in that reflective strips formed with longitudinal V-shaped grooves are provided along one or more sides of said one or more solar cells on the first intermediate layer, prior to said second intermediate layer being provided.

13. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, wherein said one or more solar cells are fitted with one or more metal strips for the collection of current, and in some cases, mutual series connection, prior to being provided, characterized in that metal strips formed with longitudinal V-shaped grooves are used.

14. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, wherein said one or more solar cells are fitted with one or more metal strips for the collection of current, and in some cases, mutual series connection, prior to being provided, characterized in that a substance or micro-roughness having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate is applied to a surface of the metal strips which will at a later stage form part of the panel surface, prior to said one or more solar cells being provided.

15. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, characterized in that a substance or micro-roughness having a large diffuse reflection over an angle greater than the critical angle for total reflection at the first surface of the bearing plate is applied to the second surface of the bearing plate, along one or more sides of said one or more solar cells, in places which correspond with one or more strip-shaped regions, prior to said one or more solar cells being provided.

16. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing

said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, characterized in that a mould is used for the laminating process, which is formed in such a manner that longitudinal V-shaped grooves are formed in the whole of intermediate layers and coating along one or more sides of said one or more solar cells, in places which correspond with one or more strip-shaped regions.

17. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, characterized in that a bearing plate is used, which is formed with longitudinal V-shaped grooves along one or more sides of said one or more solar cells on the second surface, in places which correspond with one or more strip-shaped regions, into which grooves said coating is pressed during said laminating.

18. A method for manufacturing a photovoltaic solar panel according to claim 1, said method comprising the steps of providing said one or more solar cells on the bearing plate, with the interposition of a first intermediate layer, applying a reflective coating to said subassembly, with the interposition of a second intermediate layer, and laminating said assembly by using heat and pressure, characterized in that a bearing plate is used, which is formed with longitudinal V-shaped grooves along one or more sides of said one or more solar cells on the first surface, in places which correspond with one or more strip-shaped regions.

19. A method for manufacturing a photovoltaic solar panel according to claims 12, 13, 16 or 17, characterized in that the angle which the normal on the walls of said V-shaped grooves includes with the normal on the bearing plate is selected such that this results in a maximum angular independence, being about 30 degrees in case of a bearing plate of glass having an index of refraction of about 1.5 in air.

20. A method for manufacturing a photovoltaic solar panel according to claims 12 - 19, characterized in that one or more of the methods according to claims 12 - 19 are used in conjunction with each other.

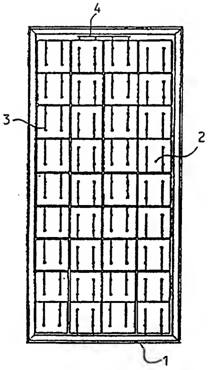

FIG. 1

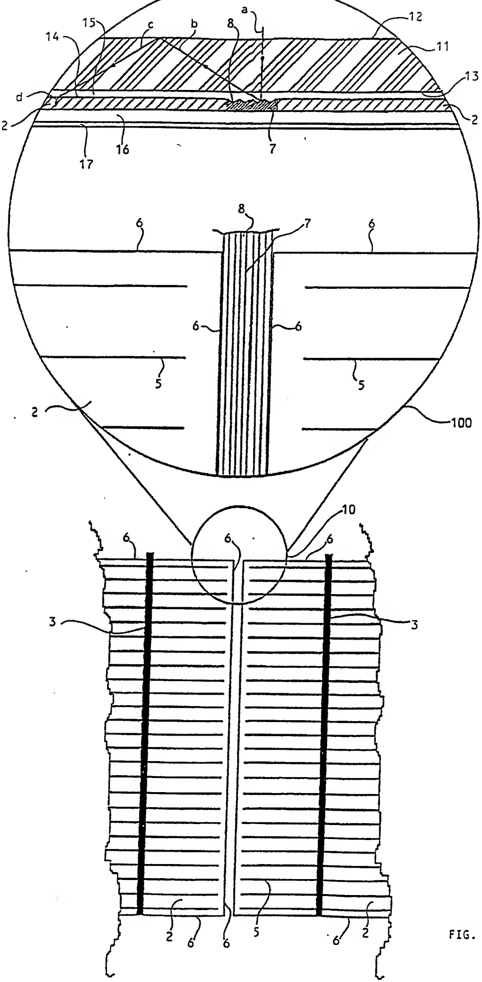

FIG. 4

FIG. 3

FIG. 2

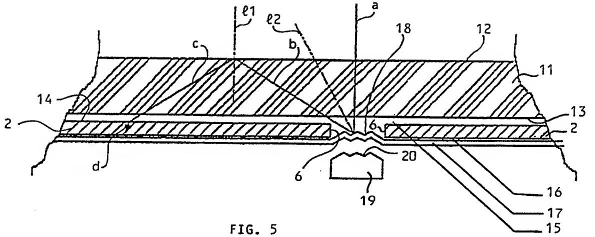

FIG. 5

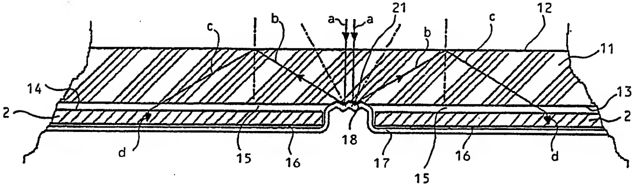

FIG. 6

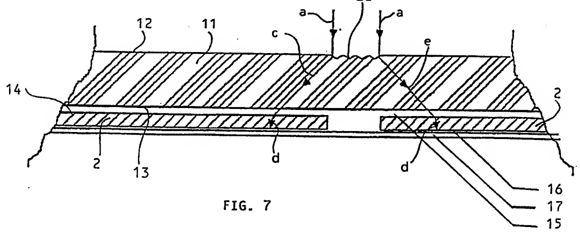

FIG. 7

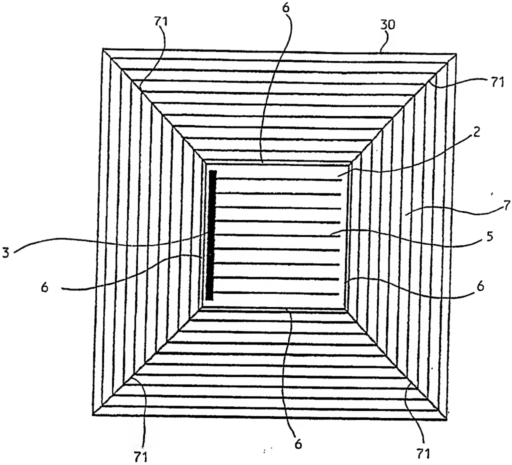

FIG. 8

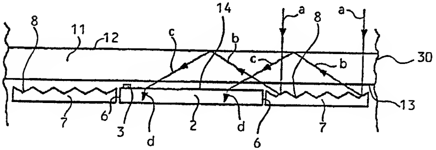

FIG. 9

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L31/052 H01L31/048

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 235 643 (J. A. AMICK) 25 November 1980 see column 3, line 15 - column 6, line 38 see figures 1-6	1-3,6,7,11
A	IDEM	5,12,13,16,17,19
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A	IDEM	12,14,15
X	US,A,4 379 202 (MOBIL SOLAR ENERGY CORPORATION) 5 April 1983 see the whole document	1-4,10,18

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
18 January 1995	03.02.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Visentin, A

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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		JP-A-	55009500	23-01-80
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